Holography:

Holography was invented by Dennis in 1948, but due to want of high coherent light i.e laser light it had to wait until 1960 to improve. The word "holo" means entire, complete, full, whole; "graphy" means recording. Hence Holography means Recording of complete information of an object. In holography light reflected from an object contains all the information of an object i.e it contains two types of information.

(1) Intensity distribution on the object

(2) phase information. i.e details of depth of an object

but in conventional photography it records only the intensity distribution on the object.

In conventional photography, we are very much familiar with negatives. Using negatives we can take a no. of +ve copies.

In a holography, the image of the object to be photographed is not recorded but the light waves reflected from the object are recorded. This photographic record is called a hologram.

When a hologram is illuminated by a coherent light source (or) laser source, a 3-dimensional virtual image of the object is formed. The process of image formation from a hologram is called "Reconstruction process."

Hence Holography is a two step process.

(a) Transformation of an object into a hologram.

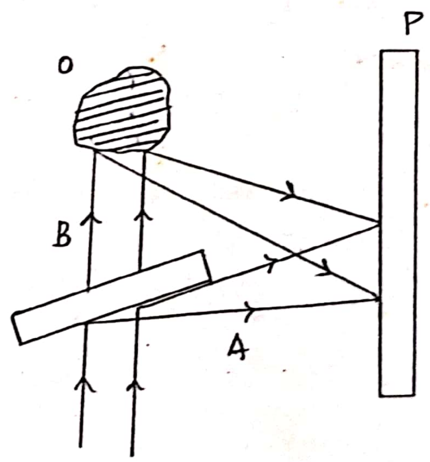
(b) Retransformation of hologram into the image of an object.

Principle: Holography is the process of image construction by recording and reconstruction of a hologram by means of interference techniques.

Construction of a hologram:

The process of making a hologram is called construction (or) Recording. The following figure shows a simple arrangement for recording hologram.

Light from a laser is split into two beams A and B by a beam splitter. The beam A is called reference beam (or) reflected beam. The beam B is called object (or) scattered beam.

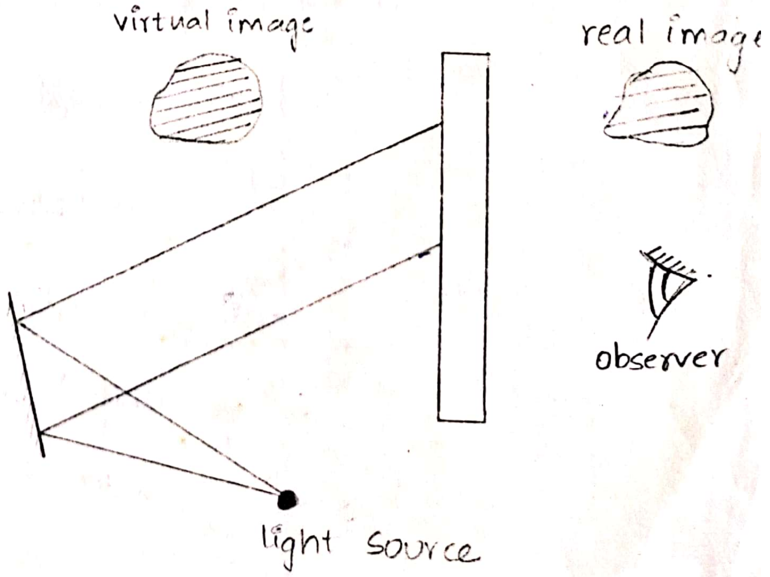


The beam 'B' is incident on the object & scattered. The scattered beam falls on the photographic plate 'P'. The reflected beam called reference beam 'A' also falls on the photographic plate 'P'. Superposition of reference and scattered beam takes place on photographic plate and results the interference pattern. The developed form of photographic film is called Hologram. Hologram consists of no. of points i.e dark and bright.

Reconstruction:

When a hologram is illuminated by a laser light, the laser beam interacts with the hologram and diffract. As a result two light source images are formed;

a virtual image on one side and a real image on the other side.



Applications:

1) Each and every piece of a hologram gives the complete information of an object, where as it does not so in conventional photography.

2) These are used to produce 3-D images of object.

3) Holography techniques are used to produce diffraction gratings.

4) It can also be used for identification of finger prints and for character recognition.

5) The most valuable information can be stored in holographic form.

6) Holography plays a very important role in often signal processing.

Differences between Photography & Holography

Photography	Holography
① For photography, we need ordinary light source	① For holography, we need Laser light source.
② We need a lens system for photography.	② No lens is required.
③ Image resolution is very low	③ Image resolution is very high.
④ In this 2-Dimensional image is formed	④ 3 dimensional image is formed.
⑤ phenomenon of Reflection, Refraction takes place.	⑤ Interference, Diffraction takes place.
⑥ It records only the intensity distribution on the object	⑥ It records intensity as well as phase information of the object.
⑦ It has less information capacity	⑦ It has high information capacity.
⑧ when it is cut into small pieces each piece will show a part of the object	⑧ If it is cut into pieces, every part gives the complete information of object

Types of Hologram :

There are two types of holograms, namely (i) Reflection hologram (ii) Transmission hologram.

Reflection hologram : If the recording material in the hologram is arranged such that the reference beam, as well as the object beam approaches it from two opposite sides, then the hologram formed is called Reflection type hologram. When such a hologram is reconstructed the reference beam and object beam lie on the same side of hologram. The interference fringes of hologram are very close to each other (very closely spaced) and hence fringe spacing is very less. The images produced in this are usually dimmer. The interference fringes on the hologram are parallel to the surface of recording material

Transmission hologram : If the recording mater-ial in the hologram is arranged such that the reference beam as well as the object beam approaches it from the same side, then the hologram formed is called Transmission hologram. when such a hologram is reconstructed, then the reference beam and object beam lie on opposite sides of hologram.

The interference frinzes are spaced apart (i.e 1 to 10 m.m) and are wider.

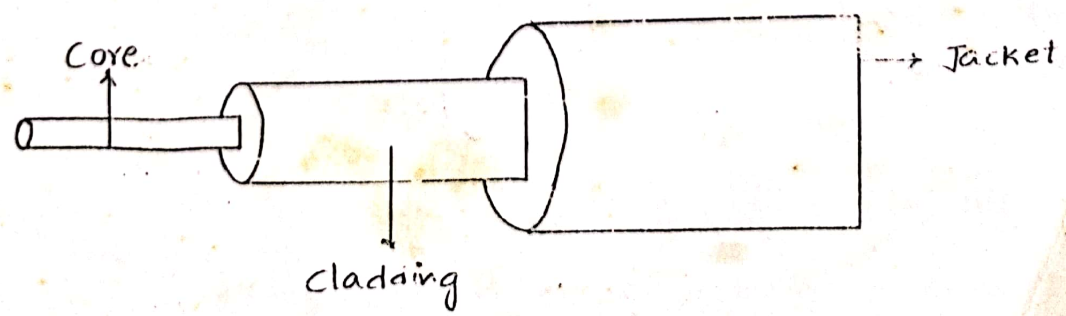
The interference frinzes are usually perpendicular to the surface of recording material.

In this the virtual image can be very clear and perspective. If this hologram is cut into small pieces, each piece will give full information of the object.

FIBRE OPTICS

An optical fibre is a very thin, flexible thread of transparent plastic or glass in which light is transmitted through multiple total internal reflections. It consists of an inner cylindrical material made of glass called core. The core is surrounded by a layer of material called the cladding. Again it is covered by a jacket. Light is transmitted within the core. The cladding keeps the light waves within the core; because the refractive index of the cladding (1·46) is less than the refractive index of the core (1·48).

The cladding provides some additional strength to the core. The addition of jacket protects the optical fibre from moisture and surrounding atmosphere. Many such optical fibres are grouped to form a cable. A cable may consist of one to several hundreds of such fibres.



Principle of optical fibre:

Once the light rays enters into core, they propagate by means of multiple total internal reflections at the core-cladding interface, so that the light rays travel from one end to the other end of the optical fibre. This is the principle of optical fibre. The phenomenon of total internal reflection in a straight optical fibre is explained as follows.

Consider an optical fibre. Let n_1, n_2 be the Refractive indices of core and cladding respectively. Consider a light ray OA which is incident at the interface of core-cladding as shown. When the light crosses the interface the light beam will be partially refracted into the cladding and reflected partially into the core.

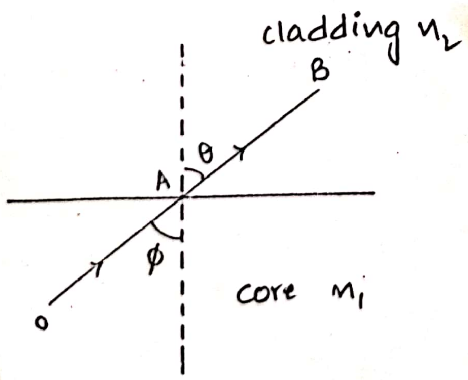


fig (a)

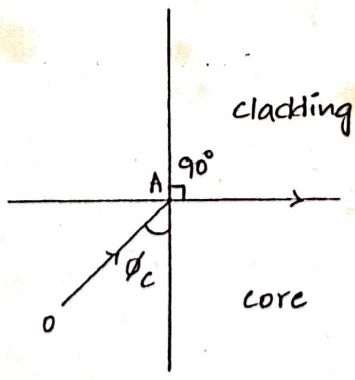


fig (b)

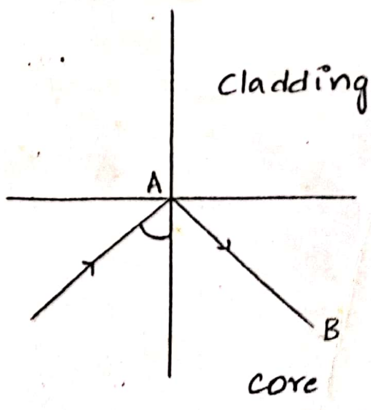


fig (c).

As shown in the fig (a), if angle of incidence ϕ increases, then the angle of refraction in cladding also increases.

At a particular angle of incidence ϕ_c, the ray travels along the boundary as shown in fig (b) i.e angle of refraction becomes $90°$ for the light ray. This angle of incidence (ϕ_c) where the angle of refraction becomes $90°$ is called critical angle

Critical Angle:

The angle of ~~the~~ incidence for the light ray at which the angle of refraction is $90°$ is called critical angle

When the angle of incidence is greater than critical angle θ_c, then the total light is reflected into the core medium as shown in fig (c). This phenomenon is called Total internal reflection.

From the refractive indexes of core and cladding, using snell's law, we have

$$\frac{n_2}{n_1} = \frac{\sin\theta_c}{\sin 90} \Rightarrow \sin\theta_c = \frac{n_2}{n_1}$$

$$\Rightarrow \theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

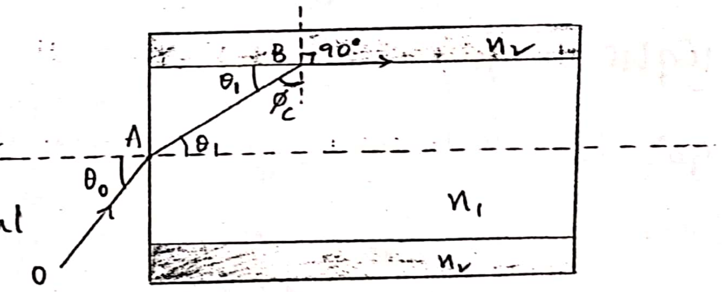
where, θ_c is the critical angle

Numerical Aperture & Acceptance angle:

Consider an optical fibre. Let n_1, n_2 be the refractive indexes of core and cladding respectively. Outside the fibre there is air medium of refractive index (r.I) 'n_0'.

Consider a light ray which is incident at the end face of an optical fibre with the incident angle 'θ_0' w.r.t the fibre axis as shown. This ray is refracted into the core with angle of refraction 'θ_1' and travels along OB.

This ray is incident at the core-cladding interface at angle equal to critical angle, so that the rays moves along the boundary.



If a light ray enters the fibre at angle less than θ_0, then the angle of refraction is also less than θ_1 and hence the angle of incidence at the interface of core and cladding is greater than ϕ_c, then the light ray is reflected into the core. i.e it suffers total internal reflection.

Only the rays incident with this maximum angle of incidence will be reflected into the core and propagated through the fibre. The maximum angle of incidence at the end face of an optical fibre for which the light can be propagated in the fibre. This is called acceptance angle 'θ_0'. These rays form a cone around the fibre axis called acceptance cone.

Expression for acceptance angle (θ_0):

From the above fig. at 'A' we have by using snell's law

$$\frac{n_1}{n_0} = \frac{\sin\theta_0}{\sin\theta_1}$$

$$\therefore \sin\theta_0 = \frac{n_1}{n_0}\sin\theta_1 \rightarrow (1)$$

By applying snell's law at B, we have

$$\frac{n_2}{n_1} = \frac{\sin\phi_c}{\sin 90^\circ} \Rightarrow \sin\phi_c = \frac{n_2}{n_1} \rightarrow (2)$$

We know that from the figure

$$\phi_c = 90 - \theta_1$$

by substituting ϕ_c value in (2), we have

$$\sin(90-\theta_1) = \frac{n_2}{n_1}$$

$$\Rightarrow \cos\theta_1 = \frac{n_2}{n_1}$$

$\therefore \sin\theta_1 = \sqrt{1-\cos^2\theta_1}$

$$= \sqrt{1-\frac{n_2^2}{n_1^2}} = \sqrt{\frac{n_1^2-n_2^2}{n_1^2}}$$

$\therefore$ From (1), we have

$$\sin\theta_0 = \frac{\cancel{n_1}}{n_0} \times \frac{\sqrt{n_1^2-n_2^2}}{\cancel{n_1}}$$

$$\sin\theta_0 = \frac{\sqrt{n_1^2-n_2^2}}{n_0}$$

$$\theta_0 = \sin^{-1}\left[\sqrt{n_1^2-n_2^2}\right] \qquad [\because n_0 = 1]$$

Numerical Aperture: (N.A)

Numerical Aperture is defined as the sine of the acceptance angle.

$$N.A = \sin\theta_0$$

$$\therefore N.A = \sqrt{n_1^2-n_2^2}$$

Let Δ be the fractional change in the refractive Index. It is defined as the ratio between difference in the refractive index of core & cladding to the core refractive index.

then $\Delta = \frac{n_1-n_2}{n_1}$

$$n_1\Delta = n_1-n_2$$

then $N.A = \sqrt{(n_1+n_2)(n_1-n_2)}$

$$N.A = \sqrt{n_1\Delta\cdot(n_1+n_2)}$$

As n_1...

As $n_1 \simeq n_2$, then $n_1 + n_2 = 2n_1$

$$N.A = n_1\sqrt{2\Delta}.$$

∴ Numerical Aperture represents the light gathe-ring capacity of an optical fibre.

Condition for light propogation in fibre:

If θ_i is the angle of incidence of an incident ray at the end of fibre, then they will propogate if $\theta_i < \theta_0$

(or)

$$\sin\theta_i < \sin\theta_0 \quad \text{(or)}$$

$$\sin\theta_i < \sqrt{n_1^2 - n_2^2} \quad \text{(or)}$$

$\sin\theta_i < N.A$ is the condition for propogation of light within the fibre

Types of Optical fibres:

Depending upon the refractive index profile of the core, they are of two types.

They are (1) Step index fibre and

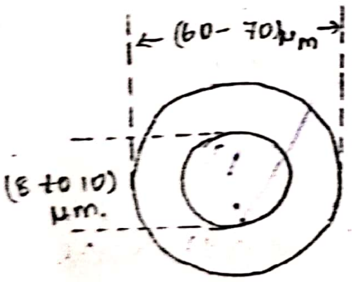
(2) Graded index fibre.

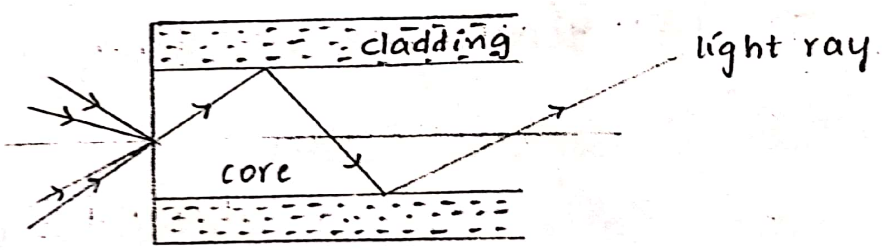
Depending upon the number of modes of propogation, optical fibres can be classified into two categories. They are single mode, multi mode optical fibres.

Single Mode Step Index fibre:

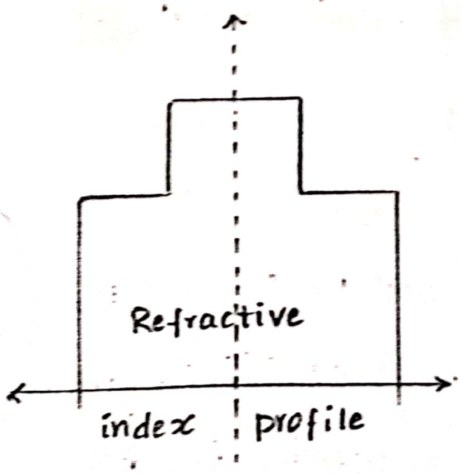
It has a core material of uniform refractive index value. similarly cladding material also has uniform refractive index, but of lesser value. In such a fibre refractive index profile abruptly changes at the junction of core & cladding. Because of this abrupt change they are called step index fibres.

The diameter of core is about 8 μm to 10 μm and the diameter of cladding is 60 μm to 70 μm. Because of its narrow core, it can just guide a single mode as in fig. below.





Single Mode step index fibre.

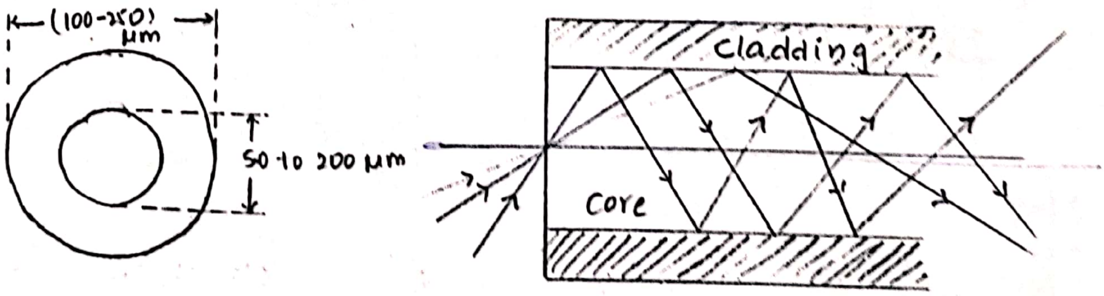


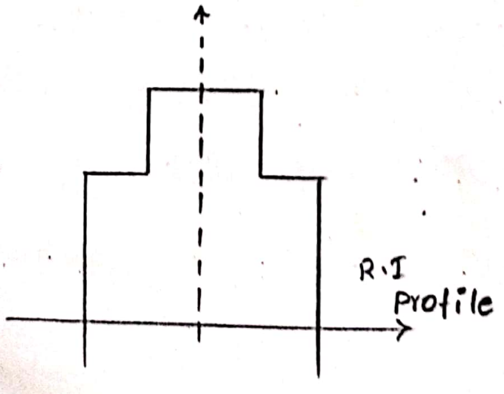
It should be remembered that single mode step index fibres support only the axial propogation.

Step Index Multimode fibre:

In this the refractive index is constant through out the core. In such a fibre R.I profile abruptly changes at the junction of the core and cladding. Because of this abrupt change they are called step index fibres. The diameter of core is 50 to 200 μm and that of cladding is 100 to 250 μm. Since the diameter of the core is large enough so that many modes can be propagated with in the core.

The light rays travelling along the axis of a fibre core are called axial rays. The light rays travelling away to the axis are called Meridonial rays.

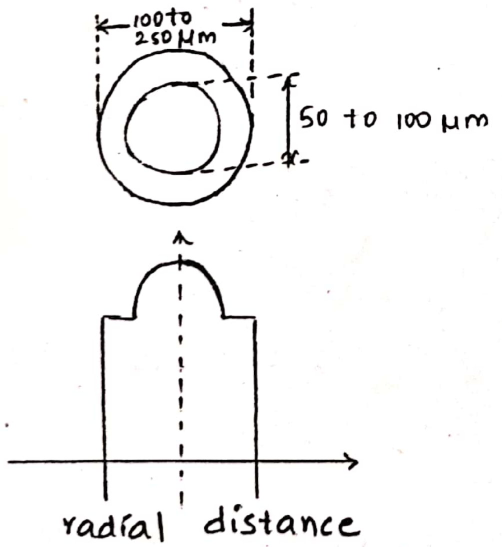


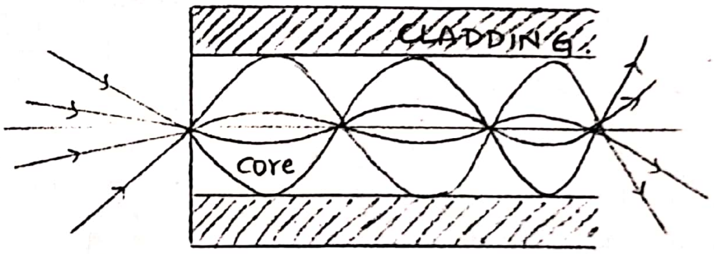


As both the rays are travelling at the same velocity with a constant R·I core, signal following the Meridonial path takes more time compared to that travelling along the axial path. The geometry of this fibre is as shown in fig above

Graded Index Multimode fibre:

In this the R·I varies continuously across the core. It is highest at the centre of the core and decreases radially towards the outer edge. It is denoted as GRIN. The geometry of this fibre is same as that of step index multi mode fibre. But the R·I of the cladding is uniform.





From the fig. axial rays follows most direct path but travels through most R·I part of the medium and hence travels most slowly. The meridonial rays travel longer distances, but lies in a medium of lower R.I, in which they travel with higher speeds comparitively.

Advantages of Optical Fibres in Communication:

1. The materials used for making optical fibres are SiO_2 and plastic, both of which are easily available at low cost.
2. Optical fibres can carry very large amount of information. Technically speaking optical fibres support transmission of signals whose frequencies are spread over a large band width.
3. Because of their compactness, light weight, small is size, fibres are much easier to transport.
4. The life span of the optical fibres is expected to be 20-30 years as compared to copper cables, which have a life span of 12-15 years.
5. Unlike in the case of metallic cables where the e-m waves are the carrier waves which can cause interference between one communication channel and the other. The optical fibres are completely protected from interference between different

Communication channels, since no light can enter in a fibre from its sides. There by purity of the signals travelling inside the fibres remains uneffected. Hence no cross-talk takes.

6. The signals generated from radio and tele comm--unication stations tend to cause disturbance in the metallic cable but cannot do so for the fibre cable.

7. Since the signal is optical, no sparks are generated as it could be in the case of electrical signal. Hence it leads to protect from corrosive and flamable environments.

Optical Fibres in Communication System:

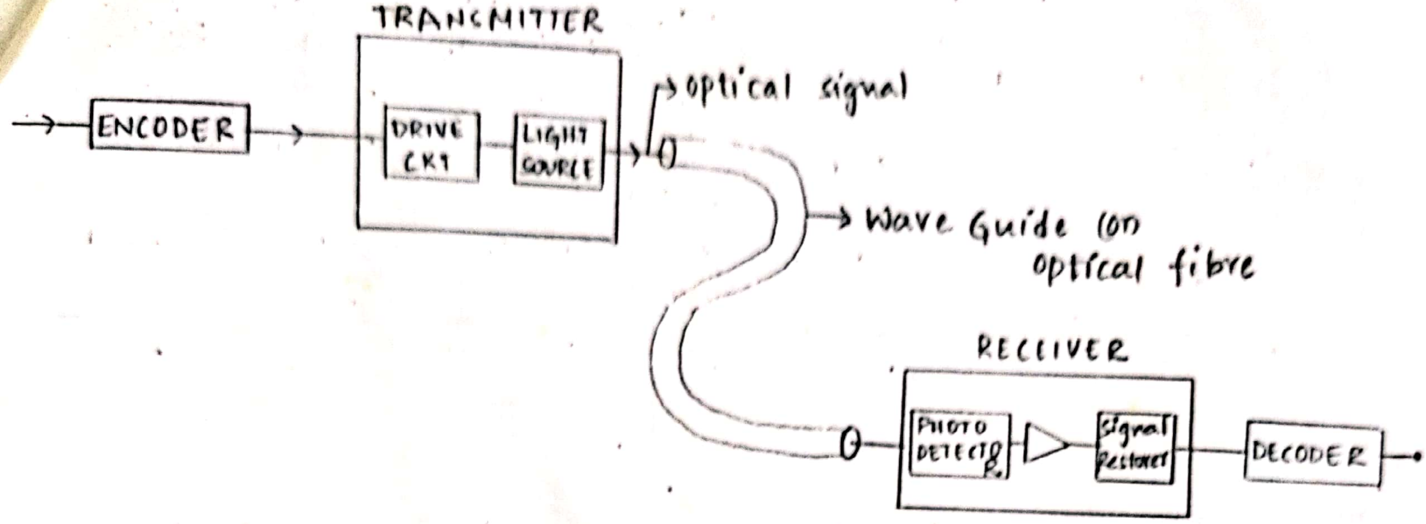
An optical fibre communication system mainly consists of the following parts.

1) Encoder 2) Transmitter 3) wave guide

4) Receiver 5) Decoder.

ENCODER:

It is an electronic system that converts the analog information like voice from a telephone (or) microphone objects into binary data. The binary contains a series of electrical pulses.



TRANSMITTER:

It consists of two parts. They are drive circuit and light source (a LED (or semiconductor Laser). Drive ckt. supplies electrical signals to the light source from the Encoder in a required form. By a connector optical signals will be injected into wave guide from transmitter.

WAVE GUIDE:

It is an optical fibre which carries information in the form of optical signals over long distances with the help of repeaters. By a suitable connector optical signal will be received by the receiver from the wave guide.

RECEIVER:

It consists of 3 parts. They are photo

detector, amplifier and signal restover. photo detector converts the optical signals into the equivalent electrical signals and supply them to amplifier. The signal restorer keeps the electric signals in a suitable way.

DECODER:

It converts the received electric signals into the analog information